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(predict$3 adj5 fail$3) and (manufactur$3 adj3 process) and (cost)	149

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Search History

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END OF SEARCH HISTORY

L1: Entry 85 of 149 File: USPT Apr 9, 2002

DOCUMENT-IDENTIFIER: US 6370437 B1
TITLE: Dynamic prediction for process control

Abstract Text (1):
Product data from a manufacturing process is analysed using techniques adapted from the study of chaos. Future values of a series of product data are predicted and an attractor structure is determined from the product data. This enables the manufacturing process to be monitored, controlled and analysed. Action can be taken to modify the manufacturing process using the results from the prediction and attractor structure to reduce costs and improve performance and efficiency.

Brief Summary Text (5):
Previously the approach of statistical process control (SPC) has been used to analyse manufacturing and other processes. Data about products produced in a manufacturing process are analysed in order to make inferences about the manufacturing process itself. For example, if the manufacturing process was for making confectionery, samples of confectionery would be drawn off at certain time intervals and analysed. Measurements for various parameters would be taken, for example, the weight of the confectionery items, the sugar content or other factors. Data from the samples would then be used to make inferences about the whole population of manufactured products and the manufacturing process. Typically, statistics such as the mean and standard deviation or range were calculated for the sample data for each parameter, and these statistics compared for different samples. For example, if the mean was observed to move outside a certain threshold range an "out of control" flag would be triggered to alert the factory staff to a problem in the manufacturing process. If trends were observed in the data, for example, an increase in the mean, the user could be alerted to this fact and then an investigation carried out.

Brief Summary Text (6):
Several problems with these statistical approaches to process control are known. For example, an inference is made that the data sets fit a standard type of distribution, such as a normal or Poisson distribution. However, this is rarely the case for process control data in which many outlying values are typically observed and which are often bimodal or show other irregular distributions. Also, data is obtained from a small sample of the manufactured products and used to make inferences about the whole population of manufactured products. This means that the statistics calculated using SPC type methods often are not an accurate reflection of the manufacturing process being analysed. Where products exhibit a high degree of consistency of performance then statistical examination of data is adequate, however, some products such as electric circuits have been found to exhibit performance results that do not fit statistical distributions, even though the data from these products fall within predetermined performance margins.

Brief Summary Text (7):
Process control is a difficult problem for manufacturers; it involves analysing the state of the manufacturing process and knowing how to adjust the manufacturing process in the light of the analysis in order to achieve efficiency and desired outputs. The manufacturer is faced with the problem of producing products that are within certain "tolerance" limits with respect to various parameters (for example,

weight of confectionery bars) whilst at the same time reducing waste. For example, in order to manufacture confectionery bars that are all of a given minimum stated weight, the majority of the bars have to be produced with a weight that is greater than that minimum. If the manufacturer were able to produce confectionery bars all with a particular weight a great cost saving could be made. However, because of the limitations of current methods of process control this cannot be achieved. Often factors to do with the manufacturing process itself are too difficult to be measured practically and so measurements from the product themselves are taken. These measurements are sometimes analysed statistically and by making simple comparisons but information about the process is not provided quickly enough and with enough precision to enable the manufacturing process to be adjusted. The information provided about the process is about the "recent past" behaviour of that process and this means that there is always a "time lag" between receiving data about the process and taking any corrective action.

Brief Summary Text (9):
Another problem in process control is being able to deal with the fact that the inputs to the process vary. For example, if components are supplied to a manufacturer for assembly into a final product, those components may vary from batch to batch and from supplier to supplier. However, it is very difficult to analyse how the components vary and this is time consuming and expensive. Also, it is difficult to determine what effect variations in the components may have on the manufacturing process that is being controlled. These problems increase for more complex products that involve many components, such as circuit boards. For this reason, many manufacturers aim to limit variability by attempting to strictly control all the initial build conditions which includes the supply base. This is often not possible if it is necessary to vary the supplier for other reasons, for example to attain a good price or to achieve continuity of supply. Many manufacturers of electronic systems rely heavily upon their suppliers to ensure that materials and components used in the fabrication of products are compliant to specification. Often, electronic components are not examined before they enter factories. Investment programmes for test equipment at the component level have shown that it is not practical to distinguish between batches of components and also that the instances of non-compliant components are negligible. For these reasons many manufacturing companies have wound down their incoming component inspection processes. Instances do occur where manufactured products exhibit changes in performance that are attributed to changes in the components but no effective way of dealing with this problem has been found.

Brief Summary Text (10):
A particular problem in process control involves the situation where a manufacturing process is set up in a particular location, such as the USA, and it is required to set up the same process in a new location, say Canada, in order to produce the same quality of product with the same efficiency. It is typically very difficult to set up the new process in such a way that the same quality of product is produced with the same efficiency because of the number of factors that influence the process.

Brief Summary Text (11):
Failure mode effect analysis is another problem in process control. In this case, a failure occurs in the manufacturing or other process and it is required to analyse why this has occurred and what corrective action should be taken. Current methods for dealing with failure mode effect analysis include schematic examination and fault injection techniques but these are not satisfactory because of the problems with the data mentioned above.

Brief Summary Text (12):
JP8314530 describes a failure prediction apparatus which uses chaos theory based methods. A physical quantity, such as an electrical signal, showing the condition of a single installation is measured repeatedly at regular intervals in order to

collect a time series of data. This time series of data is then used to reconfigure an attractor which is used to predict future values of the time series. These predicted values are compared with observed values in order to predict failure of the installation. This system is disadvantageous in many respects. The input data must be repeated measurements from a single apparatus taken at regular intervals. However, in practice it is often not possible to obtain measurements at regular intervals. Also, JP8314530 does not address the problems of dealing with product data and non time series data such as product data obtained from many products which will vary. Also, JP8314530 is concerned with failure prediction only and not with other matters such as monitoring performance and detecting changes in behaviour of a process. Moreover, JP8314530 does not describe the process of identifying nearest neighbour vectors and determining corresponding vectors for these.

Brief Summary Text (27):
This provides the advantage that product data from a manufacturing process can be analysed and used to provide a prediction about performance of the process in the future. This removes any "time lag" between obtaining data about the manufacturing process and allows immediate modification of the manufacturing process to reduce waste. This reduces manufacturing costs and improves efficiency. The manufacturing process can be effectively controlled using the product data despite the fact that this data may not fit a recognised statistical distribution and is not suitable for statistical analysis. The effects of inputs to the manufacturing process, such as new suppliers and new batches of raw materials is monitored or controlled without the need to carry out measurements or tests on the inputs. In the case that the manufacturing process fails the failure situation can be analysed by comparing the predicted and actual product data.

Drawing Description Text (2):
FIG. 1 is a schematic flow diagram of a manufacturing process.

Detailed Description Text (4):
product data--product data comprises information about items produced from a manufacturing process. The items may be whole products or components of products.

Detailed Description Text (5):
series of product data--an ordered number of items of information about items produced from a manufacturing process where the intervals between the items of information are not necessarily regular.

Detailed Description Text (10):
In the present invention, a factory or manufacturing process is assumed to be a non-linear close coupled dynamical system. Product data from the manufacturing process is assumed to contain information about the dynamical system and is analysed using techniques adapted from dynamical systems analysis. Ideally, the controller of a manufacturing process desires the manufacturing process to fit a fixed, periodic or quasiperiodic function. In this situation, the manufacturing process is easy to monitor and control because the process fits a simple function. However this is not the case in practice where it is found that manufacturing processes are very difficult to control and predict. It has unexpectedly been found that product data sometimes show characteristics of low order chaotic systems where the order of the system is between about 3 and 8. In this situation, global stability but local instability is observed, with sensitive dependence on initial conditions and with divergence of nearby trajectories in the attractor structure.

Detailed Description Text (11):
FIG. 1 shows how the invention is used to monitor results from a factory. Suppliers 10 provide components to a factory 11 via a supply path 15. The factory 11 assembles the components to form products. Each product is measured or tested to obtain values of one or more parameters. These measurements comprise part of a

number of factory results 16. The factory results 16 comprise any information related to the performance and output of the manufacturing process. For example, factory results 16 can comprise information about events in the factory and information about suppliers and any other factors which affect the manufacturing process.

Detailed Description Text (13):
The products produced by the factory 11 are provided by a shipment path 20 to customers 13. Information from the customers 13 about the products is fed back to the computer system 12 as shown by field feed back arrow 17 in FIG. 1. This information is analysed by the computer system and used to predict future performance of the manufacturing process.

Detailed Description Text (14):
Outputs from the computer system also comprise descriptions of the process occurring in the factory. On the basis of this information, adjustments are made to the manufacturing process which enables continuous improvements 19 in the manufacturing process to be made. Outputs from the computer system 12 are also used to provide feedback 14 to the suppliers about how their supplies affect the factory results 16.

Detailed Description Text (26):
As explained above an ideal manufacturing system is one for which the process is described by a simple function. By describing the attractor structure of a series of product data, the user is able to monitor this structure and adjust the manufacturing process until the attractor structure becomes simpler. In this way the manufacturing process can be improved.

Detailed Description Text (29):
FIG. 4 is an example of a method for predicting future values of a series of factory data. Factory data is provided in the format of a matrix 41 although any other suitable format can be used. Each row in the matrix represents one product produced in a manufacturing process and each column represents a series of factory data. For example, one column can be a series comprising the gain of each of a number of electric circuits produced by a factory. One of the series is taken and data from a first part 42 of this series is used for a learning phase during which a computer system "learns" or analyses the series in order to forecast future values of the series. A remainder part of the series 43 is then used to test the accuracy of the prediction.

Detailed Description Text (30):
During the learning phase, data from the first part 42 of the series are analysed using a method as illustrated in FIG. 7. A matrix is formed as illustrated in box 22 of FIG. 2 where each column represents a successive time delay applied to the first part 42 of the series of product data. The time delay is determined as described in detail below. For a current vector, one or more nearest neighbour vectors are determined as shown at box 46. The current vector comprises a most recent value of the first part 42 of the series of product data so that the current vector represents the most recent information about products produced from a manufacturing process. For each nearest neighbour vector, a measure of similarity between that nearest neighbour vector and the current vector is less then a threshold value. The measure of similarity is distance for example. The next stage involves determining a corresponding vector for each nearest neighbour vector. Each corresponding vector comprises values of the series of product data that are a specified number of data values ahead of the data values of the nearest neighbour vector in said series of product data. These corresponding vectors are then used to calculate the predicted future value of the series of product data. For example this can be done by calculating an average of the corresponding vectors. Alternatively, a weighted average of the corresponding vectors can be calculated. For example, the weighting can be arranged so that vectors which relate to earlier

times in the series of product data produce less influence on the result that vectors which relate to more recent times in the series of product data. The actual value of the series of product data is obtained, from the remaining part of the series 43, which corresponds to the predicted value, the actual and predicted values are compared. Outputs are then provided to a user on the basis of the actual and predicted values as shown in FIG. 8.

Detailed Description Text (37):
FIG. 8a shows a graph of product data values against measurement number. An upper limit 81 and a lower limit 82 are shown and these represent tolerance limits set by the factory controllers; products should fall within these limits otherwise they will be rejected. Predicted values 83 and real or actual values 84 are shown where the predicted values are obtained using a computer system according to the present invention. If the real value is within the tolerance limits but the predicted value is below the lower limit, then flag 1 (800) is presented to the user. In this case the prediction indicated that the manufacturing process was going to produce a product that did not meet the tolerance limits, but the manufacturing process improved. If the real and the predicted value are both above the upper limit 81 then flag 2 (801) is presented to the user. In this case the user is alerted to a worrying phenomenon in the manufacturing process. If the real value is below the lower limit 82 and the predicted value is within the limits then flag 3 (802) is presented to the user. In this case an unexpected change in the dynamics of the manufacturing process has been observed. FIG. 8a shows only one example of a system of flags that can be used to provide the user with information about the manufacturing process. Other methods can also be used to provide this information to the user.

Detailed Description Text (38):
FIG. 8b is an example of a truth-table for interpretation of the results of the prediction process. The table contains columns which relate to whether the prediction was met 85 or not met 86; whether the condition of the manufacturing process was good 87 or bad 88 (e.g. whether the product data was within the tolerance limits or not); and whether the actual product data had changed by a large 89 or a small 90 amount compared with the previous data value. For all the different combinations of these conditions, an interpretation is given in the column marked 91 and an opportunity flag is given in column 92.

Detailed Description Text (39):
The prediction results can also be combined with other information about the manufacturing process. For example, information about changes in suppliers and batches and about changes in temperature or humidity in the factory are recorded and taken into account with the prediction results. In this way the manufacturing process as a whole is better understood because the effects of changes in the factory, product design, suppliers, and other factors that affect the product are monitored and analysed.

CLAIMS:

21. An apparatus for controlling a product manufacturing process comprising:

(i) one or more inputs arranged to receive information about products produced in the manufacturing process said information comprising a series of product data, comprising a plurality of values each measured from a different product; and

(ii) a computer system for predicting at least one future value of said series of product data as claimed in claim 20.

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L1: Entry 62 of 149 File: USPT Sep 23, 2003

DOCUMENT-IDENTIFIER: US 6625511 B1
TITLE: Evaluation method and its apparatus of work shop and product quality

Brief Summary Text (6):
On the other hand, as a method or procedure for performing in advance a quality evaluation of an article to be manufactured before failure has actually occurred, there is known an FMEA (Failure Mode and Effects Analysis) technique (described in NIRKAGIREN: Reliability Engineering Ser. 7 "PRACTICAL USE OF FMEA, FTA") which is primarily adopted at the stage of designing a product or article to be manufactured. According to this procedure, an evaluator himself or herself predicts failure phenomena which may occur in association with individual component parts constituting a product and summarizes the "failure phenomena relating to the individual parts in the form of a table. Thus, by referencing the table, the evaluator himself or herself can predict "what sort of influence a product to be manufactured will suffer when a failure takes place". In this way, high-quality design having substantially no unintentional omissions can be realized.

Brief Summary Text (14):
With the present invention, it is contemplated to solve the problems described above by providing a product quality evaluating method which makes it possible to evaluate/estimate the failure occurrence likelihood of a manufacturing workshop (including a factory) which is scheduled to manufacture a given product by performing manufacturing works such as assembling, processing and/or the like at a premanufacturing stage such as a designing stage, a manufacturing process planning stage or the like, to thereby allow the quality such as, for example, work-related defective ratio and the like of the given product to be manufactured through a series of manufacturing works in the above-mentioned manufacturing workshop. With the present invention, it is also contemplated to provide an apparatus for carrying out the method mentioned above and a recording medium for storing the same.

Brief Summary Text (15):
Another object of the present invention is to provide a method of evaluating the failure occurrence likelihood of a manufacturing workshop, which method makes it possible to evaluate/estimate failure occurrence likelihood of a manufacturing workshop (including a factory) which is scheduled to manufacture a given product by performing manufacturing works such as assembling and/or the like at a pre-manufacturing stage such as a designing stage, a manufacturing process planning stage. With the present invention, it is equally contemplated to provide an apparatus for carrying out the method mentioned above and a recording medium storing the same.

Detailed Description Text (18):
FIGS. 3 and 13 is a configuration diagram showing an exemplary embodiment of the present invention which is 5 directed to a workshop evaluating unit 10a designed for evaluating through estimation the real abilities (sum totals of the failure occurrence ratios and workshop-based fractions defectives) of the manufacturing workshops and a product evaluating unit (manufacturing work evaluating unit) 10b for estimating the fraction defective upon manufacturing of a product or component parts of the product at a manufacturing workshop(s). In the description which follows, it is presumed that a product or article is manufactured through

assembling process and thus the assembling implicitly means the manufacturing. Parenthetically, the product evaluating unit 10b designed for estimating the fraction defective in the manufacture of a product or subassemblies thereof is described in JP-A-10-334151. Accordingly, description of the product evaluating unit will be made only briefly.

Detailed Description Text (19):
The evaluation apparatus 10 according to the present invention is comprised of an arithmetic unit 3 which in turn is constituted by a CPU 32 connected to a bus 35, a ROM 31 storing a predetermined program or programs therein, a RAM 33 designed for storing temporarily various sorts of data and the like, an input means 1 connected to the arithmetic unit 3 by way of an interface 34, a display means 2, a storage unit 4a and b and an output unit 5. The input means 1 is constituted by a keyboard, a mouse, a recording medium, a network and/or the like so that part attaching operation information 1b1 concerning the attaching work of component parts, information 1b2 concerning properties of attachment-destined parts and attachment-subjected parts, check process presence/absence information 1b3 and manufacturing workshop's name or identifier information 1b4 as well as manufacturing workshop conditions or statuses information 1a required for evaluation of the manufacturing workshop and the like can be inputted. The display means 2 is so designed that it can display an input operation aiding or prompting image upon inputting of various information with the input means 1, results of evaluation performed for manufacturing workshops (diagnosis data, improvement advices and others) and results of evaluation (fraction defective of products or articles, failure phenomena, manufacturing cost and others) concerning a product structure (objective for manufacturing work). The storage unit 4 is comprised of a manufacturing workshop evaluation-dedicated storage area 4a where a manufacturing workshop evaluating database 4a1, a manufacturing workshop evaluating computation program 4a2 and a manufacturing workshop evaluating input/output control program 4a3 are stored on one hand and a product structure evaluation-dedicated storage area 4b where a product structure evaluating database 4b1, a product structure evaluating computation program 4b2 and a product structure evaluation-dedicated input/output control program 4b3 are stored on the other hand. The output unit 5 is constituted by a recording medium, a network or the like which is provided separately from the display means 2 so that the output unit can output the results of evaluation concerning the manufacturing workshop and the results of evaluation concerning the product structure. Further, the evaluation apparatus 10 is connected to a design system 20 by way of a network or through the medium of a recording medium or the like so that design data concerning products or articles to be manufactured can be inputted to the evaluation apparatus.

Detailed Description Text (78):
Next, description will turn to the manufacturing cost computing module (CPU 32) 134 incorporated in the product evaluating unit 10b and comprised of an assembling cost computing module 134a, an assembling-failure-ascribable loss cost computing module 134b and a total cost computing module 134c. The unit prices of the attachment-destined parts are supplied from the design system and stored in the product structure evaluating database 4b1. Further stored in the product structure evaluating database 4b1 are the work time demanded for each species of standard attaching operations, work time supplementing coefficients which correspond to the supplementing coefficients for the attachment-destined part status, the attachment-subjected part status, operation sequences, the check process presence/absence status, respectively, and the costs per unit work time corresponding to the manufacturing workshop constants, respectively. Thus, the assembling cost computing module 134a can arithmetically estimate the assembling costs on the basis of the standard-attaching-operation-based work time, the work time supplementing coefficients and the costs per unit work time which correspond to the manufacturing workshop constants, respectively. Furthermore, since the fraction defective of the products on the whole and the totalized standard-attaching-operation-based fraction defective can be computed, the assembling-failure-ascribable loss cost computing

module 134b is also capable of estimating the work time taken for disassembling the product in order to replace a defective attached part by an attachment-destined part of good quality on the basis of the data which are used for computing the assembling cost. In that case, there will arise the necessity of taking into account the unit price of the attachment-destined part of good quality and the cost involved in discarding the defective attachment-destined part. Besides, in case the defective attachment-destined part is processed to be recycled as an attachment-destined part of good quality, the cost involved in such repair process may also have to be taken into account.

Detailed Description Text (79):
As is apparent from the above, the total cost computing module 134c is capable of computing the manufacturing cost of a product or assemblies of product by summing up the totalized assembling cost computed by the assembling cost computing module 134a, the total loss cost ascribable to the assembling failure as computed by the assembling-failure-ascribable loss cost computing module 134b and the sum total of the unit prices of the attachment-destined parts.

Detailed Description Text (80):
As can be understood from the foregoing description, the fractions defectives of the products or the subassemblies estimated by the product-structure-related fraction defective computing module 132, the failure events or phenomena estimated by the failure event estimating module 133, the manufacturing costs of the products or subassemblies estimated by the manufacturing cost computing module 134 can be outputted to the display device 2 or the output unit 5 together with the names or identifiers of the products or the subassemblies.

Detailed Description Text (84):
Thus, by making use of the evaluation apparatus 10 according to the present invention in the course of the product developing/manufacturing processes, the defectives occurring in the manufacturing process as well as the defectives making appearance on-the market can be reduced remarkably, as a result of which the reliability of the products for shipping can be enhanced significantly.

Detailed Description Text (85):
According to the teachings of the present invention, it is possible to evaluate or estimate the likelihood of occurrence of failures/defectives of products/articles in manufacturing workshops (inclusive of a factory) where the products/articles are scheduled to be manufactured through assembling or processing processes at a stage which precedes to manufacturing such as a design stage, manufacturing process planning stage or the like, whereby the quality such as the work-ascribable fraction defective of the products/articles manufactured through a series of manufacturing works in the workshop(s) can be estimated/evaluated with a high accuracy, and thus the defective occurrence prevention/defective extraction activities can be conducted rightly to the point in the design/manufacture/quality securing departments, to the advantageous effect that the reliability of the products for shipment can be enhanced drastically.

Detailed Description Text (86):
Furthermore, according to the teachings of the present invention, the estimated values of the fractions defectives of given products can be deduced with high accuracy on a manufacturing work basis in precedence to the actual manufacturing of these products, e.g., at a product design stage, manufacturing process planning stage or the like, enabling thus the manufacturing works of large fraction defective coefficients to be extracted or identified discriminatively without any appreciable difficulty, as a result of which the fractions defectives of the products can be reduced efficiently and effectively by taking measures for improving the manufacturing works. Thus, products designing and manufacturing can be realized with enhanced reliability. Further, according to the teachings of the present invention, it is possible to evaluate or estimate with high accuracy the

likelihood of occurrence of defects of products in a manufacturing workshop (inclusive of a factory) where the products are scheduled to be manufactured through assembling processes at a time point preceding to the manufacturing such as at a design stage, manufacturing-process planning stage or the like. Thus, improvement of the manufacturing workshop can be implemented in advance, to advantageous effect.

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L1: Entry 25 of 149 File: PGPB Jan 9, 2003

DOCUMENT-IDENTIFIER: US 20030009290 A1
TITLE: Predictive method

Summary of Invention Paragraph:
[0040] As explained in greater detail below, the methodology of the present invention has broad application in predicting the occurrence of events for which past data is available. Applications include, for example, the forecasting of vector-borne diseases, so that preventive measures can be taken and to allow predictions of the demand for treatments such as pharmaceuticals. Similarly, the method can be used to forecast the incidence of agricultural blights or pests and the corresponding demand for pesticides or other chemical treatments. In the pharmaceutical industry, the method assists in designing new drugs in the form of particular molecules or compounds by predicting their efficiency, and also in implementing their manufacture. The method is also useable in designing microprocessors optimized for speed, efficiency, low cost or ease of manufacture. In the area of utility service, the system accurately predicts customer demand in order to optimize power grid operations. In all areas, the system can be used to predict equipment failures, so that appropriate equipment maintenance and replacement can be undertaken on a timely basis. In retailing and wholesaling, the system can be used in Customer Relationship Management and the forecasting of customer behavior at e-commerce sites or other sale sites. The system can even be used by banks and other financial institutions to predict interest rates.

Detail Description Paragraph:
[0154] In the field of Customer Relationship Management (sometimes referred to as "CRM"), the system has wide applicability. By tracking purchasing patterns for individual customers and groups of customers, and generating suitable NSS indicators, the system can predict with surprising accuracy a given customer's purchases or interests over a future time period. This allows vendors to present to a customer the particular types of goods and services that the customer is interested in purchasing, at the particular time that the interest is ripe. in electronic and other retailing, especially at e-commerce sites, large amounts of data is accessible regarding the interests and buying habits of individual and groups of customers. The amount of data, in fact, is so considerable that it exceeds the ability of existing techniques to process it effectively. The present system can apply a set of numeric sequence strands to such data to generate relatively reliable predictions of what an individual customer is likely to purchase during a given period of time in the future and the probable volume of his purchases. It will also indicate the price sensitivity of customers, the general types of goods and services the customer be interested in, and the cost/benefit analysis of focused marketing for individual customers. The system can also use historic data to optimize the formatting of an e-commerce site, by the positioning of captions and product service names on the screen, by appropriate color selections, and by formulating mailing lists.

Detail Description Paragraph:
[0156] In newer utility service, the operation of a power grid can be optimized by forecasting consumer demand, by predicting equipment failure, and by forecasting transmission and distribution losses. All these can be derived with considerable accuracy based on past data and appropriately tailored numeric sequence strands.

For example, in forecasting demand, the method can predict hourly demand on a unit basis well in advance. This allows utility companies to optimize power procurement from feeder units. The lead time available through this method allows utilities to take necessary actions to eliminate load mismatches. The forecasting of equipment failures allows utilities to shift from time-based maintenance, i.e. maintenance conforming to a time schedule regardless of actual need, to event-driven maintenance, i.e. maintenance performed when actually needed. This can dramatically reduce maintenance costs by reducing unnecessary maintenance, at the same time as it dramatically reduces equipment failures by ensuring that maintenance is performed when necessary. In forecasting transmission and distribution losses, the users can predict future power losses and load mismatches well in advance, and assist them in identifying the most economical and effective solutions.

Detail Description Paragraph:
[0167] Using this technology, the system can also optimize using the paradigm in the forecasting technologies. The optimization can be used throughout all industries, including but not limited to the pharmaceutical industry, in design, testing, synthesizing and manufacturing new therapeutic molecule's and compounds, in increasing computer processors, in optimizing power grid operations and consumption, in consumer conservation of energy, in optimization of manufacturing process as well as customer relationship management, and in inventory control. To this end the users can conduct operations more efficiently and effectively whether in marketing, manufacturing or sales of any products or services or in any other business that uses processes or that has customers.

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L1: Entry 32 of 149 File: PGPB Sep 12, 2002

DOCUMENT-IDENTIFIER: US 20020128810 A1
TITLE: Systems and methods for simulation, analysis and design of automated assembly systems

Summary of Invention Paragraph:
[0007] Methods and commercial systems are known for computing detailed timing estimates for automated machinery and other equipment and processes found in typical assembly systems. These systems include three-dimensional (3-D) visualization and are generally described as 3-D factory simulation systems. Examples of such commercial systems are RobCad from Technomatix, Inc., IGRIP from Dassault/Deneb, and CimStation from Adept/Silma. These systems may be used to compute accurate times for some machine motions and other factory processes. However, they provide few, if any, methods for predicting failure rates due to tolerances or other error sources. Therefore, these systems are not applicable to the simulation of the overall automated assembly.

Summary of Invention Paragraph:
[0021] According to other various exemplary embodiments, the systems of this invention utilize a failure model based on both product tolerances and process tolerances; a kinematic and dynamic simulator; a discrete event simulator; and a financial model. In various embodiments, the failure model and the kinematic and dynamic simulator provide data to the discrete event simulator, the discrete event simulator simulates operation of the automated assembly system to obtain a throughput and a yield for the automated assembly system, and the financial model determines a cost of the automated assembly system based on the simulated operation and fundamental data of resources included in the automated assembly system.

Detail Description Paragraph:
[0036] This invention provides methods and systems for computing the productivity of a flexible assembly system and employs CAD models for 3D visualization. An automated assembly manufacturing system is called productive if it produces a large number of functional assemblies per unit time while keeping the overall cost to build and operate the assembly system low. For designing assembly systems that are productive, these systems and methods have been developed that integrate techniques to deal with the issues of, for example: timing of elemental operations of automated machines and processes; failure rates of elemental operations due to part and equipment tolerances; effects of conveyance, buffering, system repair times, etc.; 3D visualization of the modeled process; and a novel financial model with capabilities tailored to modem flexible assembly systems.

Detail Description Paragraph:
[0037] The central metric of productivity of an assembly system is the number of good units produced per unit time. For example, the number of cellular phones produced by a certain assembly line, stated in terms of the number of "good assemblies per hour". One might also speak of "system throughput," the total number of units produced per unit time, and "system yield," the percentage of units produced which are "good". The product of system throughput and system yield gives the number of good units produced per unit time. Another important metric of an assembly system is its cost to build and operate.

Detail Description Paragraph:
[0038] The previously unsolved problem is to integrate a large number of elemental pieces of data and use them to compute the number of good units produced per unit time. Examples of elemental data fall into three major categories: timing, failure, and cost.

Detail Description Paragraph:
[0041] A good assembly system not only produces a lot of functional assemblies per unit time, but also does not cost a great deal to create and operate over time. Assembly systems are generally combinations of human workers, flexible machines such as industrial robots, and hard automation. Each of these resources has certain costs associated with them. For much of the content of a flexible assembly system, the financial community has well-established methods for accounting for the various hard and soft costs, depreciation, and other factors. However, some of the financial impacts of flexible automation, such as reprogramming and re-use, are not captured by traditional accounting methods. Examples of elemental data that contribute to the financial viability of a system include, but are not limited to: cost of equipment; depreciation rate for various types of equipment; cost of system failures; capture of re-useable portion of equipment during change-over; product change-over time; part feeding and packaging costs; labor rates; cost of floor space; and net present value of capital.

Detail Description Paragraph:
[0049] The Line Module 300 may comprise one or more Yield Tables 310, one or more Action Tables 320, a discrete event simulator 330 and a resource database 340. As shown in FIG. 2, the Line Module 300 may also include a financial model 350 and line layout tools 360 that provide added functionality and capability to the system. The resource database 340 provides fundamental data to the Yield Table 310 and/or the financial model 350 according to the automated assembly system being simulated, analyzed and/or designed. For example, fundamental data may include equipment mean time before failure (MTBF), equipment tolerances, tool capabilities, sensor capabilities and costs such as equipment costs, parts cost, labor rates and the like.

Detail Description Paragraph:
[0055] The method and system allow one to study a factory line that is used to build products that are comprised of two or more parts. When two or more parts are joined together, the result is referred to as an assembly. Adding a new part into the assembly is called part insertion or equivalently, part mating. The method and system deal with many of the details of part mating, which can fail in practice. When a part insertion fails, time must be spent fixing or clearing the problem, and the part and/or the assembly may need to be scrapped. These occurrences must be accounted for in the simulator for computations of cost and throughput to be accurate.

Detail Description Paragraph:
[0076] The Yield Module 100 may utilize the DAC Design Tool from Sony Corporation, which includes types of assembly processes, scoring an assembly and other factors. Additional details of this software are described in "Design for Assembly/Disassembly Cost-Effectiveness Manual," Copyright 1996 by Sony Corporation, which is incorporated by reference herein in its entirety. The Yield Module 100 preferably includes an implementation of, and/or an extension to, the SONY "DAC" system of scoring assemblies of parts. This SONY "DAC" system may be implemented as one of the tools available in the Yield Module 100.

Detail Description Paragraph:
[0080] The DAC Design Tool from Sony Corporation is a system that implements a method that can be referred to as Design for Assembly/Disassembly Cost-Effectiveness. This method is a scheme that can be applied in the very early stages of a project by product designers and/or manufacturing engineers. The DAC Design

Tool encourages the designer of the product and/or the automation system to consider the types of assembly processes that will be used to assemble each portion of the product. The graphical user interface of the DAC Design Tool presents the user with choices to indicate the manner of assembly, such as, for example, press fit, gluing, screwing and snap fit. The DAC Design Tool also forces the user to consider the direction from which parts are assembled into the assembly. For example, having all parts coming in from one direction, such as from above, makes the required automation system simpler to design and cheaper to build. The DAC Design Tool also forces the user to consider the need to turn the sub-assembly over and other re-orientations that will be required during the assembly process. Generally speaking, such re-orientations add expense and time to the assembly scheme.

Detail Description Paragraph:
[0097] The percentage of parts that can be fit into the assembly is computed. In the case of Insertion Yield, this value does not depend on chamfers or manufacturing processes, but is a function of the parts only. For example, Insertion Yield assumes that given two parts to fit together, as much time as necessary may be spent jiggling and coercing them until they go together. Hence, in normal manufacturing situations, Insertion Yield should be a number quite near to 100%. Only in the case of very tight tolerances in combination with wide part variations should the Insertion Yield drop. Insertion Yield, therefore, is the upper limit of the success rate for an actual attempt at insertion with automated machines. A later computation takes into account chamfers and manufacturing process tolerances to compute the overall assembly success rate for each given part.

Detail Description Paragraph:
[0140] In the methods and systems of this invention, all capital equipment is organized in a resource database according to different categories, for example, conveyors, feeders, robots, tools, etc. The resource database provides a way of storing all kinds of information related to such equipment. Examples of the information stored in the resource database include, but are not limited to: costs, depreciation rates, timing information and tolerance information. For example, a parts feeder would be categorized as bowl, gravity or tape parts feeders, and would be associated with a cost and a presentation tolerance, representing how precisely it present parts. Organizing all the information about the capital equipment in the resource database provides a way for users to build libraries of the equipment they use in their assembly lines. Once entered in the resource database, the information can be re-used easily in future simulations.

Detail Description Paragraph:
[0236] Equipment Error Repair Costs: Average Number of Errors Per Hour derived from the simulation; Average Time To Repair Error (Hours) derived from the simulation; and, Annual Cost of Repairing Errors computed from the above in this display panel.

Detail Description Paragraph:
[0237] Line Costs: Equipment Hourly Rate (uses Depreciation) $/hr derived from the simulation; Labor Cost (Operators) $/hr derived from the simulation; Labor Cost (Production Workers) $/hr derived from the simulation; Annual Labor Cost derived from the simulation; and, Total Equipment Cost derived from the simulation.

Detail Description Paragraph:
[0238] Cell Costs: Equipment Hourly Rate (uses Depreciation) $/hr derived from the simulation; Labor Cost (Operators) $/hr derived from the simulation; Labor Cost (Production Workers) $/hr derived from the simulation; Annual Labor Cost derived from the simulation; and, Total Equipment Cost derived from the simulation.

Detail Description Paragraph:
[0240] Costs For Entire Assembly: Cost Of Assembly (part costs--no packaging)

derived from the simulation; Sales Price of Assembly (for changeover cost) adding up the cost of the parts; Annual Assemblies Produced derived from the simulation; Annual Cost of Scrapped Assemblies derived from the simulation; Annual Packaging Cost (from part packaging) derived from the simulation; Annual Assembly Cost (no packaging) derived from the simulation; and, Annual Assembly Cost (including packaging) derived from the simulation.

Detail Description Paragraph:
[0241] Costs Per Part: Cost Per Part (excluding packaging) derived from the simulation; Packaging Cost Per Part derived from the simulation; Parts Scrapped Per Year derived from the simulation; Parts Used Per Year (not scrapped) derived from the simulation; Total Parts used Per Year derived from the simulation; Annual Cost of Packaging derived from the simulation; Annual Cost of Scrapped Parts derived from the simulation; and, Annual Total Cost Of Parts derived from the simulation.

CLAIMS:

18. A system for determining a costed-throughput of an automated assembly system, comprising: a failure model based on both product tolerances and process tolerances; a kinematic and dynamic simulator; a discrete event simulator; and a financial model, wherein the failure model and the kinematic and dynamic simulator provide data to the discrete event simulator, the discrete event simulator simulates operation of the automated assembly system to obtain a throughput and a yield for the automated assembly system, and the financial model determines a cost of the automated assembly system based on the simulated operation and fundamental data of resources included in the automated assembly system.

First Hit Fwd Refs

Generate Collection Print

L1: Entry 59 of 149 File: USPT Oct 14, 2003

DOCUMENT-IDENTIFIER: US 6633821 B2
TITLE: System for sensing factory workspace

Brief Summary Text (4):
With the advent of modern lean manufacturing methods, information processing systems, and the Internet, factories or manufacturing facilities are increasingly gaining the ability to acquire, process, and utilize workflow information. For example, most current printshops consist of isolated machines that do not interface well with internal computer systems. Companies often organize these machines in patterns and arrays within a factory workspace that are not optimal from an efficiency and cost standpoint. For instance, the machines require operators to load/unload jobs, monitor job progress, pass jobs on to a next station, and commence a new job. In-between each of the steps, each job is commonly stored in storage areas awaiting the next step of the job. An experienced manager plans and schedules each machine. Typically, a job card that specifies the steps needed to complete the job, the steps already completed, and the order of the steps, accompanies the job. An operator manually adds the data regarding job completion to a job card, or sometimes simply holds such information in his or her memory for a period.

Brief Summary Text (9):
For the foregoing reasons, there exists in the art a need for a system and method for collecting data to analyze workflow and diagnose potential problems and machine faults within a production/manufacturing process, such as a printshop.

Detailed Description Text (2):
The present invention generally relates to the collection of data for analysis of workflow and machine diagnosis within a factory or manufacturing process, such as a printshop. For purposes of illustration, a printshop forms the foundation for the description of the manufacturing process. However, the applicant intends that the teachings of the present invention extend beyond printshops to a number of different manufacturing processes.

Detailed Description Text (25):
According to another aspect of the present invention, the combination of the acoustic sensing with the tag system enables prediction of failure. If failure associates with various acoustic/vibrational signatures, or machine 36 aging accompanies changes in acoustic signatures, this invention can help to readjust workflow based on changed probable failure modes. For example, in the previous example of two machines 36, if Machine#1 is emitting characteristic of an increased probability for breakdown or enhanced aging, the operator can decrease the lot size, increase the initial buffer loading, or reschedule jobs to alternative workflows to avoid the particular machine 36.

L1: Entry 52 of 149 File: USPT Feb 3, 2004

DOCUMENT-IDENTIFIER: US 6687558 B2
TITLE: Manufacturing design and process analysis system

Parent Case Text (2):
The present application is a continuation-in-part application of co-pending and commonly-owned U.S. patent application Ser. No. 10/067,704 filed Feb. 4, 2002 entitled "Manufacturing Design and Process Analysis System," which is incorporated herein by reference for all purposes.

Brief Summary Text (2):
The present invention relates to manufacturing, design, tooling, and process engineering and, in one embodiment, to methods, apparatuses and systems facilitating the design, tooling, production and/or measurement tasks associated with manufacturing and other processes. In one embodiment, the present invention relates to decision-making and logic structures, implemented in a computer software application, that facilitate all phases of the design, development, tooling, pre-production, qualification, certification, and production process of any part or other article that is produced to specification.

Brief Summary Text (4):
The world of manufacturing, including process engineering, has been under continuous and accelerating pressure to improve quality and reduce costs. This trend shows signs of further accelerating rather than decelerating. From a manufacturing perspective, quality refers to producing parts that 1.) are close to or at engineering design targets, and 2.) exhibit minimal variation. The realm of design engineering has also been under continuous pressure to improve quality and reduce costs. Design engineering must create nominal design targets and establish tolerance limits where it is possible for manufacturing to produce parts that are 1.) on target and 2.) that fall within the design tolerance limits. In-other-words, engineers are tasked not only with designing articles to meet form, fit and function, but with designing them for producibility.

Brief Summary Text (5):
In any manufacturing or other process that depends on the laws of engineering and physics to produce a useful result, there are five fundamental elements (see FIG. 1): 1) the process that makes the product (A); 2) Inputs into the process (B); 3) Output from the process (C); 4) Process control variables adjusted to influence the process output (D); and, 5) uncontrolled process variables that influence the process (E) (e.g., either uncontrollable variables or variables that are left uncontrolled because of time, cost or other considerations, collectively referred to as "noise.").

Brief Summary Text (14):
In light of the foregoing, a need in the art exists for methods, apparatuses and systems facilitating design and manufacturing processes and, more particularly, addressing the problems discussed above. For example, a need in the art exists for methods and systems that allow for reductions in time and cost associated with the measurement, recording, analysis and reporting processes discussed above in connection with, for example, SPC studies, Process Capability studies, shipping inspection and receiving inspection. A need in the art exists for methods to

determine how to adjust inputs to a process in order to achieve the desired outputs. A need in the art also exists for methods and systems facilitating a determination of how many article characteristics (e.g., dimensions, performance measures, etc.) should be measured for a given process. Lastly, a need in the art exists for methods and systems that enable an assessment of which article characteristics should be measured for a given process. As discussed in more detail below, embodiments of the present invention substantially fulfill these needs.

Brief Summary Text (17):
The present invention uses analytical techniques to accomplish the preceding objectives and advantages. As discussed below, graphical techniques, in one embodiment, can optionally be used in place of analytical techniques. Graphical techniques, including but not limited to charts, graphs, and plots, can also be used to display analysis results. The present invention employs powerful statistical methodologies that, in one embodiment, allow for a determination of which and how many article characteristics should be measured, potentially reducing the cost and resource expenditure associated with measurement, recording, analysis and reporting. Embodiments of the present invention also assist design engineers in designing articles for producibility. Embodiments of the present invention can also be configured to provide critical information necessary for design engineers and tooling engineers to modify design requirements for process inputs in order to make it possible for manufacturing to hit design targets and stay within specification tolerance limits. Embodiments of the present invention can also be employed to identify, using a systems engineering approach, which article characteristics have the most restrictive targets and specification tolerance limits. Such information, for instance, allows for an evaluation of whether or not tolerances should be increased and, if so, which tolerances and on which article characteristic. The present invention can also be employed to reduce the cost of performing process capability studies by reducing, in some cases dramatically so, the number of process capability studies that must be conducted. These and other aspects of the present invention will be become apparent from the following description of preferred embodiments of the present invention.

Detailed Description Text (4):
The present invention utilizes several graphical, statistical and mathematical techniques directed to analyzing the relationship between article characteristics to achieve a novel design and manufacturing process analysis system. Among these are scatter diagrams, correlation coefficients, coefficients of determination, linear, non-linear and multi-variate regression, prediction intervals, adjusted prediction intervals, prediction using regression, prediction using prediction intervals, DOE, averages and weighted averages. FIG. 3 is a process diagram illustrating how an aspect of the present invention differs from prior art techniques. In a wide variety of manufacturing processes, and injection molding in particular, there is often a strong relationship between article characteristics resulting from a given process. The present invention assesses the statistical strength of these relationships and, when they are sufficiently strong, capitalizes on their existence to facilitate a variety of design, production and measurement tasks associated with manufacturing processes.

Detailed Description Text (11):
There is a second advantage to inducing variation in an experimental run that is not connected with any efficiency measure associated with using DOE. This second advantage lies in the fact that the present invention, in one embodiment, identifies the process control settings that have the greatest impact or influence on the part characteristics. The present invention may also rely, in part, on the experience of the injection molding press operators and associated manufacturing and process personnel to select those "high impact" control settings. It should be noted that in injection molding, the usual paradigm is to minimize changes to the press settings. In contrast, the present invention seeks to maximize their impact for purposes of inducing part variation for further analysis. In-other-words, for

the purpose of inducing variation, the present invention seeks out the "worst" control settings. The "worst" control settings from a production perspective become the "best" control settings from the perspective of inducing variation.

Detailed Description Text (18):
For didactic purposes, the description of preferred embodiments primarily details application of an embodiment of the present invention to injection molding processes. The present invention, however, has application to a variety of manufacturing processes, such as plating, semiconductor manufacturing, machining, and any other process where material is added, subtracted, or otherwise changed in form or structure. In addition, the present invention can be applied to aid the design of a manufactured article, the development of a process to manufacture the article, and/or the reduction of measurement costs. Moreover, the present application has application to a variety of articles, including stand-alone articles or items, as well as articles intended as components, elements or parts of a combination. Accordingly, the description of the preferred embodiments set forth herein refers to "articles" and "parts" interchangeably.

Detailed Description Text (32):
As discussed above, the present invention can be applied to a set of articles where variation of the article characteristics occurs naturally or is induced by varying process control variables associated with the process that creates the article. When articles are produced with unchanged process control settings, there is typically little natural variation in the resulting article characteristics. This is particularly true for injection molded plastic parts. Measurement error may obscure or otherwise render unreliable the natural variation observed from a given set of articles. If it is not cost effective to use more precise measuring instruments, then variation should be induced in the parts by varying process settings. Accordingly, in a preferred embodiment, article variation is induced when measurement error is large compared to natural part variation.

Detailed Description Text (34):
Article variation can be induced by selecting and varying press settings based on the experience of the operator. That is, the operator can use his experience to determine which process settings to change in order to induce variation in the parts. To induce variation in a preferred form, the operator varies the process settings during the manufacturing process and allows the process to come to equilibrium between setting changes before selecting parts for measurement. In addition, the operator in a preferred embodiment of the method selects the set or subset of process settings that induce the greatest variability in the article characteristics of interest. In a preferred embodiment, the upper and lower limits for the process settings are chosen such that the process produces parts without harming the process equipment or tooling. Moreover, in a preferred form, the magnitude of the changes in process settings is chosen to induce variation across the full range between the article characteristic upper and lower specification limits for each of the article characteristics of interest.

Detailed Description Text (37):
As discussed in more detail below, the use of DOE to produce a set of articles for analysis provides "bonus" information that can be used, after analysis according to the present invention, to move a given article output closer to target and to reduce variation in the articles. For example, such information allows the operator to adjust press settings to accomplish the following during production: 1) move product output to target, and/or 2) minimize product variation, and/or 3) minimize cost, and/or 4) minimize press cycle time.

Detailed Description Text (62):
FIG. 16 illustrates a method involving selection of a predictor characteristic according to an embodiment of the present invention. As discussed above, data input module 102 is operative to receive and store article characteristic data associated

with a set of articles (e.g., article characteristic values and design targets/specification limits) (step 202). In one embodiment, correlation module 106, as discussed in more detail below, is operative to perform calculations (e.g., such as the determination of correlation coefficients between all combinations of article characteristics, computation of overall predictive capability of each article characteristic, etc.) to rank article characteristics according to their relative predictive capabilities. In one embodiment, display module 108 displays the ranked list of article characteristics and allows for selection of an article characteristic as the predictor characteristic (see step 204). As discussed below, a user may choose a predictor characteristic based on a number of considerations including relative predictive capability, feasibility/cost of measuring the article characteristic, etc. Still further, the selection of a predictor characteristic may be based on other methods (see below).

Detailed Description Text (95):
In another embodiment, process analysis system 100 can test to determine the values of the upper and lower prediction boundary values at the upper and lower specification limits of the predictor characteristic and determine whether these values (coordinates) lie within the compliance area. The following provides illustrative examples for didactic purposes. FIG. 23 is a flow chart illustrating a method for generating a Constraint Table according to one embodiment of the present invention. In one embodiment, many variables and other inputs used in computing the constraint table are taken from the output of other analytical processes. For example, a correlation package and other procedures compute the regression model and input the slope, intercept and boundary interval offsets of the regression model, in one embodiment, into an array, such as a spread sheet file. The slope, intercept and boundary interval offsets as well as other previously computed values, are used by process analysis system 100 to compute Pmin and Pmax and populate the Constraint Table. As FIG. 23 illustrates, process analysis system 100, starting with the first predicted characteristic (see step 702), computes the upper and lower prediction interval (boundary) values for the predicted characteristic at the upper (USL) and lower (LSL) specification limits of the predictor characteristic (step 704). For didactic purposes, FIG. 24 illustrates the left upper boundary value 241, the right upper boundary value 242, the left lower boundary value 243 and the right lower boundary value 244. In one embodiment, a method calculates the boundary values at the upper and lower specification limits of the predictor characteristic based on the regression model, including the upper and lower prediction intervals, between the predictor characteristic and the predicted characteristic. Process analysis system 100 then determines whether these boundary values (see FIG. 24) are within the four corners of the compliance area 250 defined by the upper and lower specification limits of the predictor and predicted characteristics. In one embodiment, a method or function is called to determine whether the boundary values computed above exceed the four corners of the compliance area 250. In one embodiment, this method returns four Boolean values corresponding to the respective corners of the compliance area 250 and indicate whether the boundary values are within their respective corners. Process analysis system 100, in one embodiment, uses these Boolean values to determine whether the potential for defects exist (step 706). FIGS. 25A-G graphically illustrate potential defect conditions between the predictor characteristic and a predicted characteristic (i.e., the potential that the predicted characteristic will exceed a specification limit within the specification limits of the predictor characteristic). FIGS. 25A-G all include a compliance area 250 defined by the upper (USL) and lower (LSL) specification limits of the predictor and predicted characteristic. As FIGS. 25A-C illustrate, a defect may result from the upper prediction interval 252 failing to fall within the region bounded by the compliance area 250. FIGS. 25D-F provide examples of where the lower prediction interval 254 associated with the regression model between the predictor and predicted characteristic does not fall within the compliance area 250. Lastly, FIG. 25G illustrates the circumstance where neither the upper prediction interval 252 nor the lower prediction interval intersects the compliance area 250. In one

embodiment, process analysis system evaluates the Boolean values discussed above to determine whether a defect condition exists. In one embodiment, if the two top corners, the two bottom corners, or all four corners are exceeded, a potential for defects exists. However, if only one corner of each pair is exceeded, there will be a constraining relation (see below).

Detailed Description Text (138):
The present invention provides further utility. It now becomes possible to determine whether the actual process variability (VAR) is too large relative to the maximum allowable range (P-range*). If this is the case, then a first option is to reduce the process variation. A second option is to increase the magnitude of the design tolerances. A third option is to do some combination of the previous two alternatives. The present invention can greatly facilitate efficiency and cost savings by requiring that the various process capability analyses discussed in this section be performed only one time for only the predictor characteristic instead of the 30 or 40, or however many total part characteristics, involved.

Detailed Description Text (164):
Lastly, although the present invention has been described as operating in connection with injection molding processes, the present invention, as discussed above, has application to a variety of processes. For example, the present invention has application to plating and semiconductor manufacturing, as well as any other process where a material is added, removed, or changed in form or structure. The present invention has application to other non-manufacturing processes where characteristics of the output are related. Accordingly, the present invention has been described with reference to specific embodiments. Other embodiments of the present invention will be apparent to one of ordinary skill in the art. It is, therefore, intended that the claims set forth below not be limited to the embodiments described above.